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CERTIFICATION

I, the below named translator, hereby declare that: my name and post office address are as stated below; that I am knowledgeable in the English and German languages, and that I believe that the attached text is a true and complete translation of the International Patent Application PCT/AT2003/000341, filed 12 November 2003, including the original specification and claims, and the amended claims filed on May 29, 2004.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Installation for drying or dehumidifying products

The present invention relates to a novel installation for drying or dehumidifying products of the most varied type or, if need be, also of larger structures, such as, for example, buildings or the like. The products to be dried are advantageously compact, lumpy or pourable and the range of the same extends from foodstuffs and construction materials to pharmaceutical products.

In the case of various products, in particular in the case of those of the foodstuff, dietary and medicine sector, it is necessary by means of drying operations to ensure that these products have a certain degree of moisture corresponding, for example, to the statutory regulations applicable in each case, or do not exceed this degree of moisture, in order to ensure, for example, their durability.

A suitable method of dehumidifying products of the most varied type is to actually heat them to relatively high temperatures, but this drying method, which has been known for a long time, is restricted to products which are not temperature-sensitive. For products which are sensitive to heating, apart from the application of vacuum, virtually the only suitable method is to allow possibly slightly heated air having a low moisture content to flow over or through them, the flow of this dry air absorbing moisture from the product and discharging it, for example, to the outside.

Furthermore, in order to achieve air having a low degree of moisture, it is known to cause it to flow through a hydrophilic adsorbent in order to extract from it there the moisture contained in it until a desired low degree of moisture is achieved. In order to

regenerate the adsorbent, which in the process is finally laden with moisture in the form of water, desorption of the absorbed water is to be carried out by heating the adsorbent and expelling the adsorbed water from the same, usually assisted by passing through a carrier gas flow, in particular an airflow.

Since energy, in particular in the form of electric current, will be in increasingly short supply in the coming years, inter alia due to the criticism of nuclear power generation, and as a consequence of the continually increasing demand from industry, it is attempted in every technical process to keep the consumption of energy, that is to say of electric power in particular, as low as possible. Conventional drying installations using dehumidifying adsorbents are very efficient, but have a high energy demand, in particular electric power demand, since in these installations the adsorbent to be dried, in whatever form, e.g. as granulation or as porous body, is normally dried by means of electric heating elements. In order to remove from the adsorbent the water absorbed by it, relatively high temperatures and thus a high expenditure of energy are thus required, the water absorbed by the adsorbent being vaporized and being discharged as essentially saturated water vapor usually into the ambient atmosphere.

A method that has become increasingly popular in recent years for the heating of hydrous or moisture-containing products consists in heating the respective product with microwaves instead of with conventional heating bars. Here, in particular in the case of inorganic moisture-containing products, there is the advantage that an inorganic product itself is essentially not heated by means of microwave energy, but rather only

the water molecules of the moisture absorbed by it and contained in it are activated and can be expelled from the product as heated water vapor.

Thus, US 4421651 A discloses a method and an apparatus in which, in order to regenerate a molecular sieve adsorbent loaded with organic vapors, provision is made to heat said molecular sieve adsorbent by means of microwave generators, in particular magnetrons.

As far as the prior art is concerned, reference is made to the follow publications.

EP 1 010 452 A1, CH 436 612 A, US 5 429 665 A, EP 379 975 A2 and US 4 038 054 A.

All of these publications disclose apparatuses for the drying of air which have two adsorbent bodies which work in alternating operation and pass periodically through an adsorption and a regeneration phase in a mutually alternating manner.

For example, EP 1 010 452 A1 discloses silica gel as adsorbent and microwave energy sources for its regeneration, and also a changeover, effected by means of a sensor-assisted control unit, from adsorption operation to regeneration operation in each case by switching off the regeneration heat sources and changing over an appropriately positioned three-way valve.

EP 379 975 A2 describes an air-drying installation, whose changeover from the adsorption operation to the regeneration operation is effected by means of a control unit, which can be supplied with temperature data from temperature sensors, to be precise as a

function of the temperature of the air after passing through the adsorbent in the regeneration state. Furthermore, it is known from this EP-A2 to draw the dehumidified air through a drying container by means of fans.

US 4 038 054 A also discloses a drying apparatus in which a rotary slide valve is rotated clockwise or counterclockwise from a certain position by a certain angle and as a result changes over in each case one of the two adsorbents to adsorption operation or regeneration operation. The fan there may be arranged downstream or upstream of the drying container.

The present invention relates to a novel installation, distinguished by a simple construction and an especially low energy demand, for drying a moisture-containing product from the group comprising individual parts and pourable material, biological material, fuels, foodstuffs, pharmaceuticals and the like according to the details of the preliminary or classifying part or preamble of claim 1.

The novel drying installation is characterized according to the characterizing part of this claim 1 in that its dehumidifying apparatus - for the provision of regeneration air - has at least one air-conduction line for the air which is expelled from the drying chamber and contains the moisture received from the product to be dried and which, as regeneration air provided for the regeneration of the adsorbent body laden or saturated with water, can in each case be directed periodically to the regeneration-air feeds or charging chambers or to one of their regeneration-air charging fans and can be introduced into one of the adsorbent

bodies in one of the air-dehumidifying chambers and can be moved through the same.

Especially preferred, and favorable with regard to the reduction of the energy demand, is an embodiment of the novel installation having periodic changeover from air dehumidifying to adsorbent regeneration, and vice versa, with a construction according to claim 2.

In the course of investigations which have led to the invention it was found that it is especially favorable in terms of energy and with regard to the drying efficiency to draw the air to be dehumidified through the adsorbent body during the dehumidifying operation, as can be seen in more detail from claim 3.

Alternatively, and with regard to an effective and at the same time protective dehumidification of a product to be dried, additional energy savings can be made if the air coming from the adsorbent body of the dehumidifying apparatus is not directed under pressure over or through the product to be dried, but rather, with vacuum remaining, this air dehumidified by means of the respective adsorbent body is directed, that is to say drawn, over or through the product to be dried after leaving the dehumidifying apparatus, as can likewise be seen as an alternative from claim 3.

For the regeneration of the adsorbent body laden with the water extracted from the air, an embodiment of the installation may be advantageous in which provision is made for the air provided for the regeneration of the adsorbent body to flow under pressure through the latter, which is to be regenerated periodically, as disclosed in claim 4.

A simple, robust and effectively controllable drying installation which is especially preferred within the scope of the invention can be seen from claim 5, in which drying installation both the air-dehumidifying operation and the adsorbent-body regeneration operation are successively effected in each case in an alternating manner, to be precise with the drying chamber in between, always only under vacuum.

Claim 6 relates to an addition to the novel installation which ensures the vacuum or suction operation of the novel installation with a high degree of operating reliability and effectiveness.

The subject matter of claim 7 is an especially preferred embodiment of the installation according to the invention, which is distinguished in particular by the fact that only a single suction fan is required, by means of which, on the suction side, in each case in an alternating manner, the air provided for the dehumidifying of the product in the drying chamber is drawn under vacuum through the first installation lane which is in air-dehumidifying operation and then through the drying space containing the product to be dehumidified, and, on the fan pressure side, the moisture-laden air drawn off beforehand is moved or conveyed as regeneration air under vacuum through the installation lane which is in regeneration operation.

Serving for even better utilization of energy is a configuration of the novel installation according to claim 8, in which the fresh or ambient air entering or drawn into the dehumidifying apparatus is preheated by means of the regeneration air which leaves the installation lane in regeneration operation, is laden with the moisture from the product to be dehumidified

and with the water desorbed from the adsorbent body laden or saturated with water, and is heated by means of the megatron which is in operation there.

Claim 9 discloses a special embodiment of the novel installation having bypass lines, which can be mutually regulated by short circuit and choke, for admixing a fresh- or ambient-air proportion of, for example, 25% to the dehumidified air coming or drawn in from the first installation lane, which in each case is in dehumidifying operation just at that moment, and directed into the drying chamber.

For the changeover, to be carried out inside the installation, from dehumidifying operation to regeneration operation, or of the three-way changeover provided for this purpose, control of the latter by means of corresponding moisture measuring sensors, connected for the flow of data to a control unit, according to claim 10 is especially preferred.

For the changeover from one mode of operation to the other, that is to say, in particular, in order to switch off the microwave generator at the end of the regeneration of the adsorbent body when at least most of the water adsorbed by the latter is desorbed by it, it can be especially favorable, as control variable, in addition to or instead of a measurement of the moisture of the moisture-laden regeneration air flowing out of or drawn off from the adsorbent body, to detect the power consumption, significantly increasing when the adsorbent is essentially completely regenerated, of the microwave generator, as can be seen from claim 11.

The invention is explained in more detail with reference to the drawing.

In the drawing, in each case schematically, fig. 1 shows a drying installation corresponding essentially to the prior art and figs 2, 3, 4a and 4b show three respectively different advantageous embodiments of drying installations according to the invention, the one according to figs 4a and 4b being especially preferred.

The air-dehumidifying apparatus 10 shown in fig. 1 and forming the essential component of a drying installation 100 corresponding to the prior art comprises essentially at least two operating lanes I and II, shown here accommodated in a common housing, of chambers or the like preferably arranged one above the other and connected to one another, to be precise with a respective feed or inlet chamber 1, 1′, arranged right at the bottom, for fresh or ambient air lu available in each case and a respective, adjoining air-dehumidifying chamber 2, 2′ which is arranged here above said feed or inlet chamber 1, 1′ and in which a respective air-dehumidifying adsorbent body 20, 20′, preferably based on silica gel, is arranged. The bottom and the top boundary wall of the dehumidifying chambers 2, 2′ in fig. 1 are each designed to be permeable to airflow, that is to say, for example, as a perforated plate, grid or the like and thus, when microwave generator or magnetron 6, 6′ is at first not switched on, allow the air which is to be dehumidified to pass from the environment through the air feed or inlet chamber 1, 1′ and to and through the adsorbent body 20, 20′ and allow dehumidified or dried air lt to be discharged from the latter after it has flowed through in the upward direction r1.

Arranged in each of the dehumidifying chambers 2, 2′ is a magnetron 6, 6′ for the microwave heating of the respective adsorbent body 20, 20′ in the course of its regeneration, that is to say for the desorption of the water received by the latter from the air to be dehumidified. In the version of the installation 100 shown here, the dehumidified air lt passes under vacuum du, that is to say under suction effect, from the dehumidifying chamber 2, 2′ into a dry-air discharge 4 common to both operating lanes I, II and having a suction fan 41 arranged there for the discharge of the dehumidified air lt into a drying chamber 7 (not shown in any more detail) containing a product 70 to be dried and passes from said drying chamber 7 to the outside.

Arranged above each of the dehumidifying chambers 2, 2′ is a regeneration-air feed or charging chamber 5, 5′ having a forced-draft fan 51, 51′ for introducing the regeneration air lr, which is provided for the regeneration of each of the adsorbent bodies 20, 20′ and is extracted from the environment U and which is directed or conveyed under positive pressure dü in the downward flow direction r2, opposed to the upward flow direction r1 of the ambient air lu to be dehumidified through the adsorbent body 20′, 20 during the dehumidifying operation EB in the first installation lane I, through the other respective adsorbent body 20, 20′ of the second installation lane II constructed like the first installation lane I and finally leaves the dehumidifying apparatus 10 outward into the circulating air U through the fresh-air feed or inlet chamber 1′, 1 serving to expel moisture-laden regeneration air lff.

While the dehumidifying operation EB is running in the first installation lane I, and the path for the air lt dehumidified during the passage through the adsorbent

body 20, 20′ is opened in the upward suction direction r1 toward the dry-air discharge 4 by means of one of the three-way changeover or closing members 3, 3′, namely the member 3, in the air-dehumidifying position se and the regeneration-air charging chamber 5, 5′ is closed in the process, the second installation lane II is switched to regeneration operation RB. In this lane II, the second three-way changeover or closing member 3′, 3, in the regeneration position sr, opens the path for the regeneration air lr in the second direction r2 from the regeneration-air feed or charging chamber 5′, 5 to the respectively second dehumidifying chamber 2′ and through its adsorbent body 20′, 20, the path from the respectively second dehumidifying chamber 2′ to the dry-air discharge being blocked at the same time.

In the dehumidifying chamber 2′, 2, the microwave generator 6′, 6 is switched on during the regeneration operation RB and expels the water, absorbed during the dehumidifying operation EB which has taken place there beforehand, from the second adsorbent body 20′, 20 in the form of water vapor, which is received and entrained by the flow of the regeneration air lr flowing through the same and is delivered to the environment U through the fresh- or ambient-air inlet chamber 1′, 1.

In order to explain the control of the novel installation, this control actually constituting an advantageous design detail and an advantageous integral part of the present invention, the basic task or function of said control is explained below.

The periodic changeover in each case from dehumidifying operation EB to regeneration operation RB and vice versa is controlled by means of the three-way

changeover or closing members 3, 3′ in each of the installation lanes I and II by means of the control unit 8, which is supplied with moisture data from the moisture measuring sensors 89, 89′, 89′′ connected to it for the flow and exchange of measuring data and arranged in each of the fresh-air feeds or inlet chambers 1, 1′ and in the dry-air discharge. If, for example, the measuring sensor 89′′ in the discharge signals a significant increase in the moisture in the dehumidified air lt, coming from the respective adsorbent body 20, 20′, beyond a predetermined limit value during the dehumidifying operation EB, or if one of the moisture measuring sensors 89′, 89 in the ambient-air inlet chamber 1′, 1 signals a significant drop in the moisture content in the regeneration air lr to the central control unit 8 during the regeneration operation RB, the latter effects a changeover from dehumidifying operation EB to regeneration operation RB in one of the operating lanes I and II with essentially simultaneous changeover from the regeneration operation RB to dehumidifying operation EB in the respective other installation lane II and I by virtue of the fact that the three-way changeover or closing member, e.g. the three-way damper 3, blocks the path toward the dry-air discharge 4 in one of the lanes I, II, namely in the lane I, and at the same time opens the path toward the regeneration-air feed or charging chamber 5, while in the respective other lane II the microwave generator 6′ is switched off and remains switched off and the three-way damper 3′ remains blocked toward the dry-air discharge 4 and is opened toward the regeneration-air feed or charging chamber 5. At the same time, the control unit 8 ensures that the fan 51′, 51 of the regeneration-air feed or charging chamber 5′, 5 is correspondingly switched on in each case.

The changeover rhythm described may be about 10 min, e.g. at a quantity of 12 kg silica gel in the adsorbent body 20, 20′ in each of the air-dehumidifying chambers 2, 2′ and at a maximum permissible respective output of the magnetrons 6, 6′, without complicated screening measures, of 1.5 kW.

In addition, or alternatively, a measuring sensor 86, 86′ connected to the control unit 8 for the flow of measuring data and intended for determining the power consumption of the magnetron 6, 6′ may be provided for the control of the novel dehumidifying apparatus 10, by means of which measuring sensor 86, 86′, during a significant increase in the power consumption of the magnetron 6, 6′, the control unit 8 is made to change over the respective mode of operation from dehumidifying operation EB to regeneration operation RB or vice versa.

With reference numerals and functions within the dehumidifying apparatus 10 otherwise remaining the same, fig. 2 shows an entire drying installation 100 according to the invention, in which - unlike in that in fig. 1, where the dehumidifying air lt is introduced under a certain positive pressure into a drying chamber 7 containing the product 70 to be dehumidified - the dried air lt coming from the dehumidifying apparatus 10 is drawn under a vacuum via the dry-air line 47 into and through the drying chamber 7 or over or through the product 70 to be dried which is located there, for which purpose no suction fan 41 - as shown in fig. 1 - is arranged here in the dry-air discharge 4 of the dehumidifying apparatus 10 according to fig. 1, but rather its function is taken over by a suction fan 71 arranged on the outlet side or in the discharge 57 for moisture-laden air lf from the drying chamber 7.

The essential feature of the inventive installation 100 according to fig. 2 consists in the recycling of the moisture-laden air lf - expelled from the drying chamber 7 via the air-conduction line 57, as shown in fig. 2 by broken lines, either directly or else in a favorable manner through a heating/cooling register 95 for setting a desired temperature and/or through a condenser 96 for setting, in particular reducing, the air moisture to a value which in each case is suitable or intended for use as regeneration air lr for the dehumidifying or regeneration of the adsorbent body 2, 2′ - into one of the regeneration-air feeds or charging chambers 5, 5′ and further into an installation lane I, II which is in regeneration operation RB in each case.

In the embodiment of the novel drying installation 100 shown in fig. 3 - with reference numerals otherwise remaining the same or otherwise being used in a similar manner - the dehumidifying apparatus 10 is divided strictly into two installation lanes I and II, the first lane of which, namely the lane I, is just at that moment in dehumidifying operation EB and the other, namely the lane II, is just at that moment in regeneration operation RB. Here, each of the two installation lanes I, II has its own dry-air discharge 4, 4′, which in each case has the function of a regeneration-air feed or charging chamber 5, 5′ in regeneration operation RB.

In the cycle stage shown in fig. 3, the suction fan 11′ located at the air inlet 12′ (now functioning as air outlet) of the second fresh-air feed or inlet chamber 1′ is put into operation, as is the further suction fan 51′ arranged at the air inlet opening of the regeneration-air feed or charging chamber 5′ (or dry-

air discharge 4′ after changing over the mode of operation EB, RB) and assisting the suction fan 11′ just mentioned. These two suction fans 11′, 51′ which are in operation ensure that the air, with fan 11 switched off at the same time, is drawn in through the air inlet 12 into the fresh-air feed or inlet chamber 1 of the first installation lane I and is drawn at a vacuum du of, for example, 100 to 400 mbar through the first moisture adsorbent body 20 and through the first dry-air discharge 4 of the first installation lane I, through the likewise switched-off suction fan 51 at the end of the air discharge 4, and further through the air-conduction line 47 into and through the drying chamber 7 containing the product 70 to be dehumidified and is then conveyed as moisture-laden air lf through the air-conduction line 57 leading out of the drying chamber 7 and - in place of fresh or ambient air - as regeneration air lr by means of the running suction fan 51′ into and through the second dry-air discharge 4′ and further through the second adsorbent body 20′, heated by means of the operating second magnetron 6′, and is finally drawn as air lff, "doubly" moistened by the product 70 to be dehumidified and by the moisture desorbed by the adsorbent body, through the fresh-air feed or inlet chamber 1′, now serving to expel this regeneration air, and is finally delivered to the environment U through the inlet opening 12′ of the chamber 1′ by means of the suction fan 11′, which maintains the vacuum du.

The suction fans 11′, 51′ in the installation lane II are switched off and the suction fans 11, 51 in the installation lane I are switched on in a periodically alternating manner by means of the control unit 8, to be precise when the power-consumption sensor 86′ of the second magnetron 6′ signals a significant increase in

the power consumed by the magnetron 6' to this control unit 8, which causes the latter to switch off the second magnetron 6' of the second installation lane II and likewise the suction fans 51' and 11' and to now switch on instead the first magnetron 6 and the two suction fans 11, 51 of the first installation lane I, so that the air is now drawn in the opposite direction first through the second installation lane II, through the drying chamber 7 and finally through the first installation lane I.

In principle, the embodiment of the drying installation 100 according to the invention which is shown in figs 4a and 4b - with reference numerals otherwise remaining the same - and which is especially preferred within the scope of the invention and saves energy and installation costs, since only one suction fan unit is required, is constructed in a similar manner to the installation 100 shown in fig. 3. However, as just mentioned, it has only one suction fan or only one exhauster 71 in the discharge line 57 for the air lf coming from or discharged from the drying space 7 and laden with moisture or water vapor due to the product 70 which is located there and is to be dehumidified. By means of this suction fan 71, fresh or ambient air lu is drawn on the suction side - as viewed overall - through the adsorbent body 20, 20' in the dehumidifying chamber 2, 2' of the installation lane I, II, which is in dehumidifying operation EB in each case in a periodically alternating manner, through the air-conduction line 47, with a cross changeover damper 357 correspondingly set by the control 8, in and through the drying space 7 and into the suction-side part of the discharge line 57 for air lf which is laden with moisture due to the product 70 to be dehumidified and is under vacuum.

On the pressure side of the suction fan, this moisture-laden air lf is delivered under positive pressure dü through the adsorbent body 20′, heated by means of the magnetron 6′ for the regeneration, in the installation lane II which is in regeneration operation RB.

For energy-saving reasons, both the fresh air lu, drawn in through the first installation lane I, before entering the lane I and the doubly moisture-laden regeneration air lff coming from the installation lane II are in each case directed in their lines 1, 1′ through a heat exchanger 111, as a result of which the fresh air lu drawn into the installation 100 is preheated.

Fig. 4a, which shows the entire installation 100, shows the position, set by the control unit 8, of the cross changeover damper 357 when the installation lane I is in dehumidifying operation EB and the installation lane II is in regeneration operation RB.

The detail in fig. 4b shows the position of the cross changeover damper 357 after the changeovers to regeneration operation RB in the installation lane I and to dehumidifying operation EB in the installation lane II, these changeovers being caused by the control 8 after corresponding moisture measuring data from the moisture sensors (not shown here) has been received.

It can clearly be seen that neither an interruption in the operation of the suction fan 71 nor a changeover of the same from suction to pressure operation is required. The suction fan 71 can thus continue to run during the respective change in the modes of operation in the installation lanes I and II.

Bypass lines 67, 67′ - bypassing the two installation lanes I, II - can also be seen from fig. 4a, these bypass lines 67, 67′ in each case branching off from the fresh-air feeds 1, 1′ and finally opening in each case into the dry-air discharge 4, 4′ upstream of the cross changeover damper 357 described above.

Upstream of the point at which the bypass lines 67, 67′ open into said dry-air discharge 4, 4′ as mentioned, a respective airflow-rate regulating/reducing or shut-off damper 677, 677′ is arranged in them.

The bypass lines 67, 67′ can serve to regulate or readjust the moisture content of the air lt fed to the drying space 7 via the air-conduction line 47 and dehumidified in the installation lane I or II, which is in dehumidifying operation EB in each case, by a fresh-air partial flow tlu from in each case one of the bypass lines 67, 67′ being admixed with said air lt, so that a respectively desired degree of drying or moisture is then ultimately present in the air lt fed to the drying space 7.

A short-circuit line 676 directly connecting the two bypass lines 67, 67′ and having a short-circuit damper 667 which can be shut off, controlled or opened in each case is provided for the changeover operation.

Furthermore, fig. 4a also shows an airflow-rate regulating or closing damper 477 in the air-conduction line 47 toward the drying space 7, by means of which the vacuum du in the drying space and thus the dehumidifying effect in the same can be regulated or readjusted.

Finally, fig. 4a also shows heating registers 401, 401′ at the respective dry-air discharges 4, 4′ for heating or preheating the dry air lt before it enters the drying chamber 7 and/or the regeneration air lf or lr, laden with moisture from the product 70 to be dried, before it enters the adsorbent body 20, 20′ to be regenerated in each case.